Assistive Device for paralyzed upper limbs using BCI

[1]Ramkumar.B, [2]Shenbaga Devi.S

[1]M.E, ECE, College of Engineering, Guindy, Anna University, Chennai, INDIA

[2]Professor, ECE, College of Engineering, Guindy, Anna University, Chennai, INDIA

Abstract: A Human assistive device to lift the forearm of the patient using Brain-Computer Interface (BCI) was designed. The electroencephalographic (EEG) activity is used as the basis for a brain-computer interface (BCI) that could be a new alternative communication channel for patients lacking useful voluntary movement. The intended movement of arms of the patient during motor imagery is classified by sensory motor rhythms (Mu and Beta band) in the EEG signals obtained during the process of imagination of arm movement.

Keywords: Brain Computer Interface, BCI, EEG, Electroencephalogram, Assistive Device

I INTRODUCTION

A Brain Computer Interface (BCI) is a system through which a person can control the external world without relying on muscle activity. BCIs are used for assisting, augmenting, repairing human cognitive or sensory-motor functions. An electroencephalogram (EEG) based Brain-Computer-Interface (BCI) provides a communication channel between the human brain and a computer. Patients who are suffering from motor impairments may use such a BCI system as an alternative form of communication by mental activity. In this work, the non-invasive BCI is designed. Non-invasive BCIs aim to either restore movement in individuals with paralysis or provide devices to assist them, by the use of computers or robot arms.

BCI systems are designed for individuals with motor disabilities to communicate with the outside world. One of the major factors of stroke is rehabilitation and is limited with 30 to 60% of patients being unable to use their more affected limb. Paralysis is the loss of muscle function in a part of our body. It occurs when something goes wrong with the way messages pass between human brain and muscles. Paralysis is most often caused by damage in nervous system and especially in spinal cord. Paralysis can be complete or partial. Impairment of motor function, such as hemiparesis or hemiplegia of the upper limbs and lower limbs. Recovery of motor function is important to do daily activities of the patient.

Event Related Desynchronization (ERD) is a reduction of amplitude in a specific frequency component and is related to an increase in neural activity. A negative ERD percentage indicates that there is a decrease in power with respect to the reference state and a positive value means there is an increase in power. Event Related Synchronization (ERS) is an increase in a specific frequency component and is related to neural suppression. Activity invoked by right hand movement imagery is most prominent over electrode location C3 and left hand movement imagery produces activity most prominent over electrode location C4.

An EEG based brain-computer interface (BCI) directly measures brain activity associated with the user's intent and translates the recorded brain activity into corresponding control signals for BCI applications. In this work the EEG signals are modified by motor imagery and can be used for automatic classification of left or right hand movements. If the classification result is right arm, the assistive device is switched on so that the patient can lift his arm. The assistive device consists of a support to lift the forearm of the patient by means of a stepper motor.

II BACKGROUND

In the work by M. Teplan (2002) [1], the author gives an introduction into EEG Measurements to help with orientation in EEG field and with building basic knowledge for performing EEG recordings. The study explained about the background of the subject, a brief historical overview and some EEG related research areas and also explains about EEG recording.

Petia Georgieva et al (2012) [3], developed electroencephalogram (EEG) based brain machine interface (BMI). The most successful BMI technologies are presented and then the protocol for motor imagery noninvasive BMI for a mobile robot control is discussed. Source based BMI is a new approach where the idea is to estimate the strength and the location of the brain most active zones by some non-invasive technique (for example EEG). The information (the signal) from the estimated source is then used in the BMI protocol for discriminating the user intentions.

Rajesh Kannan Megalingam et al (2012) [4], developed an EEG acquisition device for a thought

controlled robotic arm. The technique lies in the mapping of the EEG signal of the subject to the 2D cursor. They designed a low cost and reliable signal acquisition device to attain the EEG signal and mapped it to cursor control through signal processing.

J.Arnil et al (2013) [6] developed a BCI-based assistive robot arm. People who lost their limbs by injury or congenital missing need prosthesis to replace the missing body part to assist or enhance the motor ability or for cosmetic purpose. Brain-computer interface (BCI) technology is proposed to assist the person with disability who has no arm. The proposed system includes two BCI algorithms, i.e. ERD/ERS algorithm and hybrid EEG-EOG algorithm. Their designed assistive robot arm is light weight, low power consumption, user friendly and pleasing aesthetic. The ERD/ERS algorithm can achieve the accuracy of approximately 66% with 3 commands.

III EXPERIMENTAL SETUP

III A. EEG SIGNAL ACQUISITION

The EEG signal is recorded in 2 channels using designed acquisition system, one channel measuring electric potential between electrodes at positions C3 with respect to Cz and ground electrode A2 in the right ear and another channel measuring electric potential between electrodes at positions C4 with respect to Cz and ground electrode A2 in the right ear. The positions of the electrodes are shown in figure 1 as shaded region.

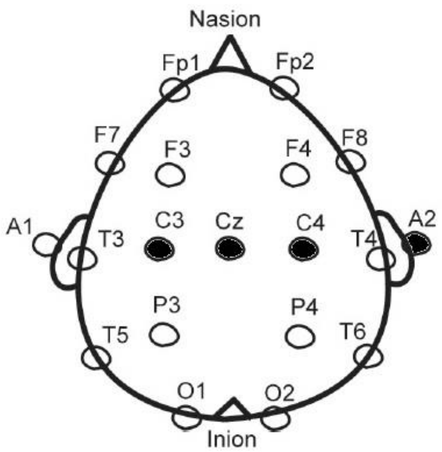

Figure 1: Electrode positions for EEG recording

The block diagram of one such channel is shown in figure 2.

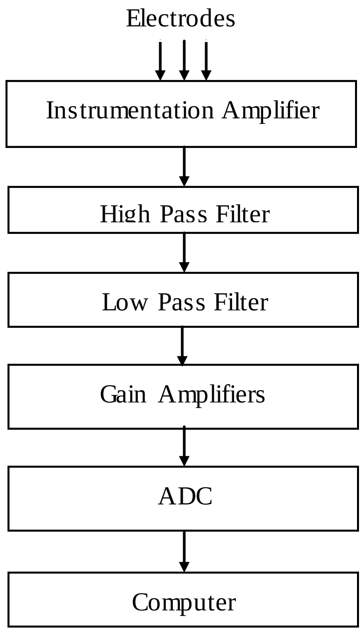

Figure 2: Block diagram of EEG acquisition system in one channel

The inputs from the electrodes are fed to an instrumentation amplifier. The output of the Instrumentation amplifier is fed to a high pass filter having a cut-off frequency of 0.5 Hz followed by a low pass filter having a cut-off frequency of 40 Hz. The output is fed to gain amplifiers. The overall gain of the system varies from 72 dB to 106 dB.

The EEG is recorded for a duration of 15 seconds. During the time, in the initial first 10 seconds, the patient is at rest and for the next 5 seconds imagines to move his/her left/right arm. The raw EEG signal obtained from the hardware is converted into digital values using NI Data Acquisition system (DAQ).

III B. CLASSIFICATION

The signals obtained are normalised using MATLAB. The mu band (8-13 Hz) and beta band (13-30 Hz) rhythms are filtered and extracted. The classification of the left/right arm is done by the features mean and power of the signal obtained in the mu band and beta band rhythms.

If the classification result is right arm, then the assistive device which helps in lifting the right arm is switched on using NI Data Acquisition system (DAQ).

III C. ASSISTIVE DEVICE

The assistive device consists of a stepper motor controlled by microcontroller. The microcontroller obtains the signal from DAQ so that a stepper motor is switched on in which the shaft is coupled to the forearm of the patient. There exists reset switch in microcontroller and if the patient feels discomfort with the assistive device the stepper motor is switched off at that instant.

In this setup, the assistive device is switched on, when the classification is right arm. The Stepper motor is operated in unipolar half stepping mode.

IV RESULTS AND DISCUSSIONS

The EEG is recorded for 7 subjects, all right-handed, age varying from 21-30 for about 10 trials of both left/right arm classification for each subject. The signal obtained in two channels during right hand imagination of a subject during a trial is shown in figure 3. Figure 4 shows the extracted mu and beta band rhytms.

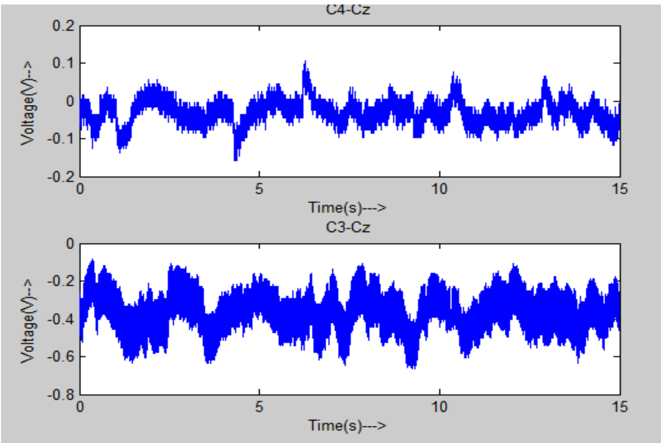

Figure 3: Raw EEG signal obtained during right hand imagination movement of a subject during a trial

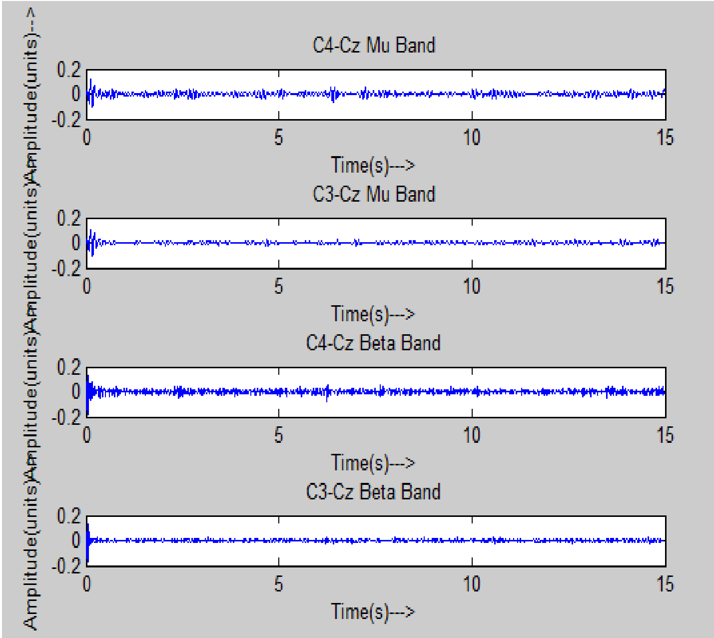

Figure 4: EEG signal obtained after signal processing during right hand imagination movement of a subject during a trial

The mean value of mu and beta bands and their mean power values are given for different conditions in table 1 to table 4.

Table 1: Mean of Mu band Mean and Band Power during Right hand imagery

Subject ID	C4 Mu Band Power (μV^2)	C4 Mu Mean (μV)	C3 Mu Band Power (μV^2)	C3 Mu Mean (μV)
1	519.27	127.14	513.99	-11.3
2	302.56	60.62	346.62	-7.298
3	437.4	-70.5	7680	-29.3
4	567.72	-110.61	168.05	227.85
5	334.4	63.13	259.05	118.91
6	86.21	15.95	341.71	62.08
7	149.54	11.92	221.43	-16.76

Table 2: Mean of Beta band Mean and Band Power during Right hand imagery

Subject ID	C4 Beta Band Power (μV^2)	C4 Beta Mean (μV)	C3 Beta Band Power (μV^2)	C3 Beta Mean (μV)

1	993.49	-7.607	950.7	16.18
2	1848.5	-34.25	1747	-1.69
3	3880	-29.01	17250	-126.06
4	316.99	44.33	760.69	41.53
5	263.15	10.82	1120	11.88
6	1263.46	26.32	820.15	26.39
7	106.99	-12.45	304.36	-15.64

Table 3: Mean of Mu band Mean and Band Power during Left hand imagery

Subject ID	**C4 Mu Band Power** (μV^2)	**C4 Mu Mean** (μV)	**C3 Mu Band Power** (μV^2)	**C3 Mu Mean** (μV)
1	190.38	-44.37	182.51	42.66
2	137.7	-90.96	175.67	-26.87
3	625.24	-105.76	8420	-471.26
4	425.63	65.42	152.87	12.82
5	398.74	32.4	170.73	36.646
6	170.52	23.65	354.42	-55.74
7	71.9	33.13	323.05	-48.55

Table 4: Mean of Beta band Mean and Band Power during Left hand imagery

Subject ID	**C4 Beta Band Power** (μV^2)	**C4 Beta Mean** (μV)	**C3 Beta Band Power** (μV^2)	**C3 Beta Mean** (μV)
1	611.18	-14.52	700.01	-4.27
2	350.2	16.28	347.98	-8.06
3	4200	8.48	22500	83.76
4	1800	13.57	541.37	43.2
5	379.45	18.68	135.22	-0.23
6	482.12	-13.93	803.82	-20.34
7	217.79	3.94	1129.1	55.65

The classification of the left/right arm is done by the features mean and power of the signal obtained in the mu band and beta band rhythms. Out of 70 trials, the classification accuracy for left hand is found out to be 74.28% and the classification accuracy for right hand is found out to be 80%. The overall classification efficiency is 77.14%. This classified output is given to the assistive device to activate it.

V CONCLUSION

The classification efficiency can be increased by extracting more features in the mu and beta band rhythms and employing neural networks. The time for classification is a major criteria for the operation for assistive device so that the assistive device is operated with small delay.

ACKNOWLEDGEMENT

The authors thank Life Sciences Reasearch Board, DRDO for funding this project. The authors also thank the Director, DEBEL, Bangalore for the continued support in this project.

REFERENCES

[1] M. Teplan (2002), “Fundamentals of EEG Measurement”, Journal of the Measurement Science, Measurement in Biomedicine Block, Measurement Science Review, Volume 2, Section 2.

[2] Noor Ashraaf Noorazman and Nor Hidayati (2009), “Portable EEG Signal Acquisition System”, The International Journal of College Science in India, Vol.3.1 February 2009, ISSN: 1939-2648

[3] Petia Georgieva et al (2012), “Brain Machine Interface – IEETA case Study”, intelligent systems (IS), 6th IEEE International Conference 6-8 September 2012, Page 374-379

[4] Rajesh Kannan Megalingam et al (2012), “EEG Acquisition Device for A Thought Controlled Robotic Arm” International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11.

[5] Leandro Bueno, Jose Luis Pons and Teodiano Freire Bastos Filho (2013), “An Embedded System for an EEG Based BCI”, IEEE Biosignals and Biorobotics conference (BRC), 18-20 February 2013 ISSNIP, Page 1-5.

[6] J.Arnil et al (2013) “BCI-based Assistive Robot Arm”, Medical Information and Communication Technology (ISMICT), 7th IEEE International Symposium on 6-8 March 2013, Page 208-212.